InSite

Canadian Well Logging Society

CWLS Magazine
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InSite

CWLS Magazine **December 2010**

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Photos: If you have a photos that the CWLS can use in its next InSite please send a high resolution jpeg format version to bruce.keen@halliburton.com or naladani@suncor.com. Include a short description of the photo with your submission.

The 2010 - 2011 CWLS Executive:

Back row (l - r): Simon Corti, Vern Mathison, Dave Shorey, Brian Glover, Harold Hovdebo
Front row (l - r): Kathy Chernipeski, Agus Kusuma, Nabil Al-Adani, Maggie Malapad
Missing from photo: Bruce Keen (new publications co-chair) and Xianfeng Zhang (new Secretary)

President's Message

The job is so nice I took it twice.

It seems like just a few short months ago, I started my second opportunity to serve as your president. As before, it remains a privilege and honor to have been selected to lead such a special group as the CWLS

The CWLS has a long and valued history of contribution to the Canadian petroleum industry and I am proud to be a member and a part of such an organization. The strength of an organization such as the CWLS lies in its membership so I feel that it is very important to again recognize those who have volunteered their time and efforts in serving the CWLS. I would like to thank those currently serving on the executive for generously giving their time and commitment in serving our society. As a special acknowledgement I would also like to thank our publications committee and their work on the INSITE magazine. Publishing the INSITE is no small effort and their commitment to getting this magazine out and to our constituents is laudable.

In addition, the society exists only through the help of the persons who dedicate time and energy to give presentations, organize and contribute to our seminars and serve on our various committees. To all of you that have done so over this past year, thank you for your most valuable contribution. Lastly, I would like to encourage each member to consider running for CWLS executive, volunteering for a convention or committee, or giving a paper at one of our luncheons.

We have had a tremendous increase in the number of student members in CWLS. To each of them, I would like to extend a special invitation to become involved. The CWLS and our sister organizations are great places to meet like-minded professionals, build friendships and extend your professional network.

To close, I would like to state that I am looking forward to serving out my term as your president, meeting the challenge of the past president position and finding new candidates for the executive. I would like once again thank the membership for granting me the opportunity and privilege to serve. I'm looking forward to seeing you all at our monthly luncheons, the AGM and other society functions.

I sincerely wish you all a warm and joyous holiday season and all the very best for the New Year.

Dave Shorey
President, CWLS

CWLS 2010 to 2011 Executive

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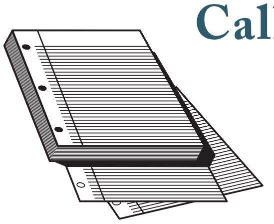

Call for Papers

The CWLS is always seeking materials for publication. We are seeking both full papers and short articles for the InSite Magazine. Please share your knowledge and observations with the rest of the membership/petrophysical community.

Contact publication Co-chair:
Bruce Keen - bruce.keen@halliburton.com or
Nabil Al-Adani - naladani@suncor.com

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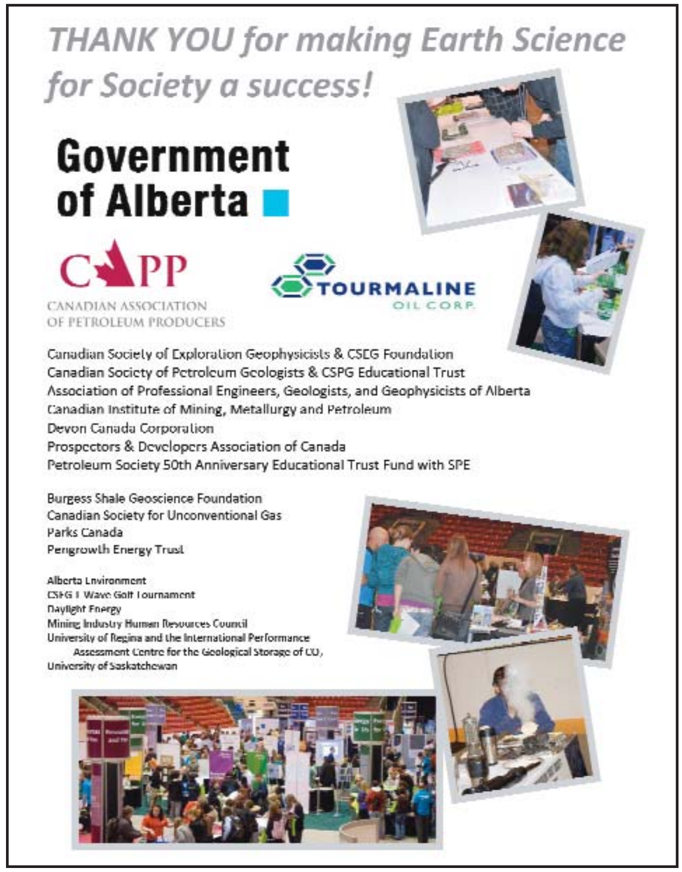
Sharing the Earth Sciences with the Next Generation

On May 10th & 11th 2010, the ***Earth Science for Society*** Exhibition (ESfS) transformed the BMO Corral into a centre of Earth Science discovery. While thousands of geoscientists gathered for GeoCanada 2010, a once a decade conference sponsored by geosciences organizations from across Canada, over 3000 Calgary and area junior high school students, teachers, parents, conference delegates and the general public explored the interactive exhibits at five pavilions: *Energy for Us, Resources and You, One Dynamic Earth, Your Career?, and Our Future!*

Each pavilion contained several exhibits offering hands-on opportunities to see and experience Earth Science in a unique way. Visitors smashed rocks with hammers to find delicate trilobite fossils, compared the weight of a meteorite to an ordinary Earth rock or peered down special microscopes at diamonds, fossils and minerals. Many visitors were captivated by the simulated coal dust explosion. The exhibitors were dynamic and the exhibits mesmerizing.

The main objective of ***Earth Science for Society*** the exhibition was to show students and the general public, through the use of interactive and dynamic exhibits, how Earth Science impacts our daily life. The ESfS exhibition was designed to supplement Alberta Education's curriculum so as to allow teachers to bring students on a field trip. The exhibition offered a rare opportunity for students to get their hands dirty and to learn about the wide impact of Earth Sciences. Last May, many gained a new appreciation for how Earth Science integrates many sciences. Visitors learned what Earth Scientists do and how important their contribution is to the things we use every day. Students were also encouraged to explore career options.



It is important that we Geoscientists pass along our enthusiasm about our discipline and educate students and the public about the invaluable contribution to society made by Earth Scientists.

The organizing committee arranged the buses and schedules for 2000 junior high school students and teachers. Each student was given a goody bag which included a scavenger hunt booklet and each teacher had an educators' handout with the answers to the questions in the booklet. 80 keen volunteer guides met the buses and escorted the students to the exhibit floor.

This program would not have been possible without the help of 20 generous sponsors, 20 volunteer organizing committee members, 80 volunteer guides and 27 exhibitors. We have received enthusiastic feedback and interest in running this successful program again next year but can only do so with additional help to organize it. If you are interested in volunteering please email outreach@cseg.ca

Kyla Poelzer

The CWLS and the InSite Magazine are

GOING GREEN!

Your CWLS Executive is proud to announce that we have adopted a greener attitude towards the way we are conducting our business. We have been working towards this initiative for some time now, especially with the introduction of our website and online presence, and we are continuing to move in this greener (and we believe) brighter and more sustainable direction!

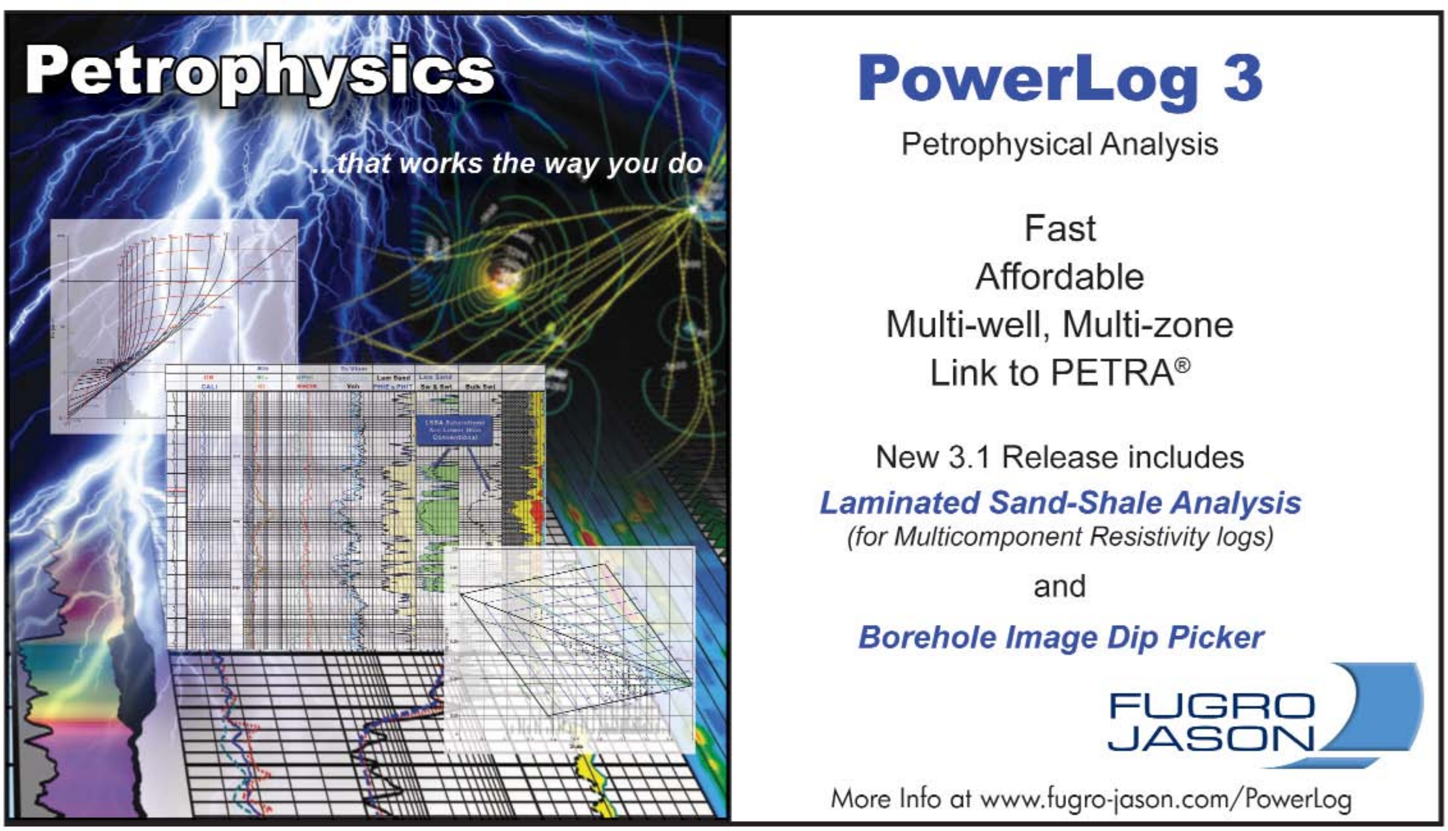
One change we are eager to implement is the way we deliver our InSite Magazine to our membership. Going forward, we will now be providing the option for you to receive your InSite Magazine electronically rather than by hardcopy through the mail. For those who do prefer, we will be continuing our regular mailout as well.

The website will shortly be updated to allow this option. Within the next couple of months, please notify us of your preference to receive the next InSite Magazine and following ones electronically, by logging onto the website at www.cwls.org. Go to "my account" at the top right-hand corner of the page, and then click on "Edit Your Profile". Toggle on your preference. You may change your preference at any time.

Note; we have uploaded past issues of the InSite Magazine onto the website as well. You can access these and other notices and publications under Publications > Papers.

Please consider joining us in this GREEN initiative.

Sincerely,
Kathy Chernipeski
Former Secretary



New Members

Laura Strumness
Geologist, ConocoPhillips Canada

John McKinley
Geologist in Training,

Michael, Dimmer
Wireline field supervisor, Datalog technology

John Aylward
Area Team Lead, Shallow Gas, Enerplus Resources

Jesse Williams-Kovacs
Student, University of Calgary

Diana Ramirez
Log Analyst, Halliburton

Paul Bazinet
IHS

Sanam Zomorodi
Engineering Intern, University of Calgary

James Deering
Petrophysicist, Talisman Energy Inc.

ShenXian Duu
Student

Dante Vianzon
Training / QC Coordinator, Datalog Technology

Sheldon Wang
Exploitation Engineer, Direct Energy

Terry Gardner
Principal Consultant, Seamless Information Consulting Ltd.

(Joanna) Feng Zhou
Senior Petrophysical Technologist, Husky Energy Inc.

Elizabeth Grace
Well Operations Manager, RPS Energy

Roger Goyette
Wellsite Geologist, Rojageological Services ltd

recovery | energy environment economy

2011 CSPG CSEG CWLS Convention

The upcoming 2011 Canadian Well Logging Society (CWLS), Canadian Society of Petroleum Geologists (CSPG) and Canadian Society of Exploration Geophysicists (CSEG) Annual GeoConvention is themed "Road to recovery - Energy, Environment and Economy." It is being branded by the organizing committee as "recovery-2011." This coming year, Satyaki Ray, Geoscience Advisor at Marathon Oil Canada Corporation, Calgary will represent the CWLS as the Convention General Co-Chair in the Convention Steering Commitee. A long time CWLS and CSPG member, Satyaki brings with him twenty two years of diverse Canadian and international oil and gas operator and service industry experience. Prior to his current role, he was involved as a society volunteer, session chair and as a veteran technical co-chair (CWLS) for GeoConvention 2009 themed "Frontiers and Innovation." Bruce Keen one of the CWLS InSite editors recently sat down with Satyaki to discuss his involvement with the joint convention and some of the themes and highlights for the upcoming event planned for May 9-13, 2011 in Calgary.

Bruce Keen with Satyaki Ray

Satyaki, can you give a short description of what the CWLS/CSPG/CSEG GeoConvention is?

The CSPG-CWLS-CSEG GeoConvention is an annual joint convention of three premier Canadian technical societies including oil and gas geologists, geophysicists and petrophysists. This GeoConvention "term" has been particularly popular since 2007. The pre-cursors of this arrangement existed prior to 2007 when several societies teamed up for a common goal; to promote the geoscientific and petrophysical quest for hydrocarbon and natural resources focused on Canada. This convention is not only restricted to Canadian articles and papers. It is intended to be an even balance of Canadian and international content so that it is attractive to a global audience. To be meaningful to an increasingly diverse workforce, especially in terms of professional background, it is necessary to include a number of topics ranging from technical and economic to environmental. "recovery 2011" will emphasize integrated topics in conventional and unconventional resources from both a local and global point of view. In addition emerging technologies and frontier topics will be continuing themes from past years. Innovation coming from younger minds will be very welcome. In fact, the mantra of the annual joint convention is to leverage diverse ideas and assimilate them in Canadian, US and international context to create economic and environmental success.

Can you describe what your roles and responsibilities will be as the 2011 CWLS Convention General Co-Chair?

This is a very interesting question. I am a General Co-Chair representing the CWLS on the Steering Committee of the 2011 Joint Convention. My peers are Paul MacKay from CSPG and Rob McGrory from CSEG. We are the steering committee who set the concept and plan the high level budget and special events for this convention. Working with these stalwarts of Canadian industry is really an exhilarating experience. As the convention is built on the technical content of these sessions, the Technical Committee working with the guidance of the Steering Committee is crucial to the execution of the convention. Simon Corti is the CWLS Technical Co-Chair for the "recovery 2011", along with his counterparts from the other two societies. Ensuring that the technical program is a 'good' fit for this year's theme, and integrating a new approach are my primary roles as a general co-chair.

The 2011 Convention is themed "recovery," which can represent and define many things. Can you elaborate on the theme choice for the 2011 Convention?

The theme was actually chosen by Paul MacKay in consultation with the organizing committee. It is opportune to call this year's convention "recovery 2011" as it is particularly reminiscent of the global turmoil in business and uncertainties in exploration and production. The recession years of 2008 and 2009 are now in hindsight, with the turn-around of 2010 just ending. There is cautious optimism that the upcoming year will see continued recovery in drilling activity, production and finances of most companies in conventional and unconventional oil and gas plays, tight sandstone and shale oil and gas, and heavy oil and oil sands. So in our mind the "road to recovery" seems a good fit to reflect the mood of the convention attendees. We encourage attendees from all disciplines and this year we may have a business recovery session in addition to several integrated thematic technical sessions. The technical committee is planning the sessions as we speak. Rudy Strobl has agreed to lead the Core Conference which we plan to revitalize this year. Our conference plans on having several high profile session chairs that are being approached at the moment by the committee. The Call for Abstracts is being updated on the website, www.geoconvention.com

What motivated you to become involved with the convention?

This is an issue close to my heart, and the answer I feel, is my diversity and how it meshes with the pulse of being Canadian. We need to give back to the technical community that we have learned from so that the knowledge sharing continues and is beneficial to all. For instance, I am a Canadian national with East Indian origin, working and practicing professional geology, petrophysics and leadership roles for about twenty two years in the industry. My Canadian stint has been the past decade, prior to which I worked and lived in various countries on short term and long term assignments with ONGC India, Schlumberger, ConocoPhillips and currently Marathon Oil Corporation. Travelling to several parts of the world on business and leisure gave an exposure to different work cultures, different mentors who demonstrated varied business models and diverse approaches to solving technical and business problems. You can call me a global citizen with Canadian nationality.

That is what motivates me to continue to give back to industry and students what I learned from these years of working in the oil and gas business. Through my transitions between technical leadership and management roles, the service industry and with operators, I learned that there is always more than one view and that we have to respect them. Marathon Oil Canada management has been very supportive of my technical roles, industry networking, and has sponsored events such as Core Conference in the convention in previous years. It is my wish that we have a good convention again in 2011. Some notable people in the CWLS who supported me previously were Peter Kubica and Roy Benteau, and I also thank Maggie Malapad, Dave Shorey and the rest of the CWLS Executive Committee for taking an active interest in the convention.

As this convention requires significant resources and time commitment from many individuals, can you comment on the volunteers and the roles that contribute to the ongoing success of this event?

The conventions would not be successful without the help of volunteers. Their time commitment, insight and desire to make the convention a success are the reason why the convention is successful year after year. Carmon Graefer with the CSPG will be this year's volunteer coordinator and she will be responsible for coordinating all volunteer activities and ensuring each volunteer role has a suitable candidate. Aileen Lozie, convention manager, will ensure that all volunteers are placed according to their preferences and areas of expertise and will ensure that their experience onsite is a memorable one. As a General co-chair, I help find individuals who have the desire and skill set required to fill committee vacancies, as these roles are crucial to the success of each convention. The measure of success the committee wants to establish is where companies see the importance of the GeoConvention and register their employees to actively involve them.

Satyaki Ray

How does someone get involved as a volunteer? Who would be the point of contact if an individual is interested in a volunteer position for the convention?

We are always looking for willing volunteers, regardless of their time commitment or previous experience. If someone is interested in participating in this year's convention, please contact Carmon Graefer, Volunteer Coordinator at volunteer@geoconvention.com or visit the convention website at www.geoconvention.com and check out the contact page for more information. If you have any suggestions for the convention in general, feel free to email at sray@marathonoil.com . Our committee remains open to tangible ideas.

Satyaki Ray and Bruce Keen

Coal Characterization by Core-flood, X-ray CT and Low-field NMR

Wednesday, January 13th, 2010 Luncheon

Our presenter in January, Dr. Rong (Grace) Guo, was also the recipient of the best thesis student award for last year. She presented her work on characterizing coalbed methane (CBM) using multi-stage core-flooding, X-ray computed tomography (CT) scanning and low-field nuclear magnetic resonance (NMR) techniques. Her project itself researched transport phenomena in coalbeds and as a result, several techniques were developed in order to better characterize CBM reservoirs. A Mannville formation coal sample was used to measure and model the flow properties, characterize coal contained fluids, and determine effects on coal permeability.

Coal itself is a dual porosity system, where the primary porosity component is the coal matrix itself, and fractures or cleats comprise secondary porosity. Desorbed methane will diffuse itself through the matrix and into the water filled cleats, to enter solution. Carbon dioxide has twice the adsorption rate in coal as methane does, and so enhanced CBM recovery has made use of carbon dioxide injection to displace methane and increase production. However, this can have adverse affects on the coal permeability through swelling and increased stress, and the permeability itself can dynamically change throughout reservoir production. Pressure changes on coal over time will end up destroying parts of the internal coal structure further decreasing the overall permeability. Using core-flooding techniques, it was revealed that carbon dioxide gas adsorption over time caused a significant decrease in permeability. One of the difficulties faced in the experiment was the time-frame to allow for sufficient, realistic adsorption which was on the order of several months. Despite these challenges, injection rates and pore volumes can be optimized to displace most of the methane without negatively impacting the permeability.

X-ray CT imaging proved to be an excellent passive analyzing tool to visualize how flow pathways changed throughout the core-flooding experiment. Density map results illustrated how fractures would partially recover after adsorption and desorption of the gases. They also shed light on the volumetric strain (and moreover its affect on permeability) that the coal will undergo throughout production due to these adsorption changes.

Dr. Rong (Grace) Guo.
(Photo courtesy of Wild Horse Entertainment)

To determine the moisture content of the coal, low-field NMR was employed. Accounting for the free and bound water components is important when determining the amount of gas that can be adsorbed. In addition, it was used to determine the coal wettability and the water, gas and coal interactions. Overall, the NMR experiments were able to identify the fluid content within the coal, the gas adsorption rates, and how coal wettability is affected by carbon dioxide injection.

Coalbed methane is already on its way to becoming a significant contributor to natural gas production in Canada, and it is very important that academic work like Grace's is recognized. The CWLS presents the thesis award to help raise awareness on both sides: students become more involved in the field of petrophysics, and the current formation evaluation community can benefit from research that is currently being done at the academic level like this. This is especially important when the implications of research of this kind will lead to the development of new tools and analysis techniques. In addition to being recognized by our society, Grace's work has also won her the Dr. S.M. Farouq Ali award in 2007 for the best paper published in the Journal of Canadian Petroleum Technology. We thank her again for coming to share her research with us.

Jeff Dickson

Downhole Fluid Analysis coupled with Asphaltene Nanoscience for Reservoir Evalution

Wednesday, March 10th, 2010 Luncheon

Our speaker was Dr. Oliver Mullins from Schlumberger, who talked about his extensive work using asphaltene nanoscience in Downhole Fluid Analysis, or DFA. Asphaltenes are the denser hydrocarbon compounds found more commonly in black oils (petroleum with low gas-to-oil ratios) that constitute an important end-member in reservoir evaluation. This falls in stark contrast with lighter crude oils, where accounting for condensate end-members is something that has been well established and incorporated into reservoir evaluation workflows.

Dr. Oliver Mullins
(Photo courtesy of Wild Horse Entertainment)

As a leading chemist who has pioneered the expansion on asphaltene science, Dr. Mullins was able to shed light on the work that has been done to incorporate these heavier end-members in formation evaluation. These new methods were used in a series of case studies, where they were able to successfully predict reservoir connectivity, biodegradation, overall reserves, and the location and flow assurance of mobile oil in heavy oil columns. These studies were able to advance the use of heavy ends in reservoir characterization, and demonstrate that these methods can be meshed with the existing DFA techniques, leading to a new generations of these tools.

Jeff Dickson

Reservoir Quality and Fluid Sensitivity

Wednesday, April 14th, 2010 Luncheon

In April we heard Richard Thom, from Core Laboratories Canada, speak on fluid sensitivity and reservoir quality pertaining to pore type. These topics addressed fines migration, or the movement of clay material through the pore system, and the potential blockages this can cause. This is not an issue unless the wetting phase of the reservoir is being mobilized, because in a water-wet reservoir the fines themselves will be entrained within that phase. However, as a well is produced and the water phase mobilizes, pore throats can become clogged with fine material if the fines are greater than one third of the diameter of those throats.

The important consideration in fines migration is that we are able to quantify the potential permeability drop that this material can represent and devise well plans that circumvent this from occurring, or at least minimize the effects. Using an acid to dissolve carbonate fines for instance may just end up mobilizing these fines to block arteries elsewhere. Adjusting the flow rates of injection can stave off mobilizing too much of the fine material. Essentially it is about weighing the pros and cons of completion strategies and achieving a balance.

Water sensitivity is important when devising a drilling plan, and this pertains to swelling (in smectite specifically) and deflocculation (in regards to kaolinite dispersal), both of which can have the end result of clogging pore spaces. The latter can be brought about by a salinity contrast between introduced water that is fresher than the formation water. Acid can be used to effectively dissolve iron-bearing carbonates or chlorite crusts in reservoirs, but once in solution, dissolved iron will eventually precipitate out as pH rises again. This is something that can be managed in the completion strategy by flushing the acid out at an appropriate time. It is also important to consider the role that bitumen can play in blocking pore spaces, as it can act as a clogging residue during production if unaccounted for.

In terms of pore types, these can be classified as effective and non-effective, and they determine the connectivity and permeability of the reservoir. When kaolinite and illite are present they can create a microporosity component which although represented in logs, does not contribute to production. Dissolution and recrystallization in carbonate reservoirs can lead to similar situations. Determining pore type and permeability, and thus estimating producible reserves can be done through mercury injection capillary pressure analysis. This technique is especially useful in distinguishing between primary and secondary porosity types.

By taking the time to understand the pore types and potential fluid sensitivity problems that can occur in a particular reservoir, many problems can be successfully accounted for and avoided by using this information to optimize drilling and completions plans.

Jeff Dickson

Common Pitfalls in Mini-Frac Analysis and Their Consequences for Hydraulic Fracture Design

Wednesday, May 19th, 2010 Luncheon

May's talk was on mini-fracture or "mini-frac" analysis and the effects that its misinterpretation can have on estimates. Robert Hawkes from BJ Services, returned to speak to us on mini-fracing, which involves estimating fracture and pressure parameters prior to implementing a full hydraulic fracture treatment in a reservoir. The objectives of mini-frac vary depending on what discipline you approach the topic from, and as Hawkes himself is a reservoir engineer, he highlighted the information he believes is important to obtain from this analysis.

Because the deliverability of a reservoir is a function of both the completion design and the rock properties themselves, the aim is always to find a balance that will provide a level of stabilized production. The mini-frac procedure involves briefly pressurizing the wellbore until the formation begins to fracture, and then ceasing the pressurization at a point which is then called the instantaneous shut-in pressure (ISIP). From here, the pressure is leaked off to gain a sense of the fracture closure pressure (FCP) which itself is essentially the minimum horizontal stress on the vertical fracture. The time between the ISIP and closure is on the order of an hour or less and pressure changes will reveal immediate properties like the fracture gradient. The after-closure analysis however, is very useful to determine the reservoir flow dynamics, but the time to really develop these signatures is on the order of hours and even up to a day, which has high cost implications.

By characterizing the stress regimes and determining the direction of maximum stress, fractures can be oriented to be far more effective. Step-up and step-down tests can be used to identify the friction and tortuosity within the reservoir that will help determine the net pressures. One of the things to be wary of is how data smoothing functions can potentially affect the determination of FCP. In the after-closure analysis, the ultimate goal is to determine the linear (or bilinear) and radial flow pressures. However, here it is easy to misinterpret or make assumptions about the flow regimes prematurely.

Hawkes argues that the largest pitfalls in mini-frac are data smoothing, flow regime identification and obtaining reservoir pressures, as these can lead quite easily to misinterpretation and faulty results. He further illustrated the kinds of affects this can have through several case studies in some diverse fields. By ignoring or not accounting for these problems, an incorrect analysis will create a false sense of security without actually providing realistic characterization of the reservoir properties, especially given the cost of these procedures.

Jeff Dickson

Tight and Unconventional Gas Reservoir Evaluation and Optimization

Wednesday, June 9th, 2010 Luncheon

Our luncheon talk in June was given by Dr. Brant Bennion of Weatherford Laboratories on how to evaluate unconventional gas reservoirs. In his presentation, Bennion focused specifically on gas shales where most of the gas is adsorbed within the matrix of the rock, and tight gas reservoirs where free or compressed gas has been trapped due to low permeability and there is a low adsorption component. The latter type of reservoir can be split into two classes: those that are under capillary equilibrium, and those that are at capillary non-equilibrium.

Reservoirs such as the Milk River or Medicine Hat which have low permeability but are at a normal capillary equilibrium will tend to have large transition zones between water and gas contacts. They will also have a large immobile water saturation component. The range of recoverable mobile fluid in these reservoirs however, sharply contrasts to those that are at a capillary non-equilibrium, which in many cases will have substantially lower water saturations. These gas reservoirs, like the Montney, are found initially to have water saturations lower than conventional drainage would be able to achieve, and are classified as being "subnormally water saturated" or desiccated. But how do these types of low-permeability reservoirs come to occur?

One hypothesis is the idea of regional dehydration. Initially, sediments were deposited in an aqueous environment and mobile water displacement begins to occur as gas is generated from the neighbouring source rock. As this gas generation and migration continues over millions of years, physically displacing the mobile water component, and dehydrating the rock by removing a portion of the immobile water into the migrating gas phase. This has the effect of increasing water salinity (thereby lowering the resistivity) in some cases to the point of super-saturation. This has large implications when estimating reserves, as using an inaccurate water resistivity will result in overestimating water saturation, and therefore underestimating gas in place.

These factors essentially need to come together to develop a production strategy that will optimize permeability and extract as much gas as possible. In these unconventional reservoirs, permeability is inherently low and requires stimulation by facing in order to generate a sufficient drainage area. The effectiveness of a fracturing regime is dependent on the play between the conductivity of the fractures, and the deliverability of the formation to transmit gas to the fractures. In these tight plays, higher conductivity can actually lead to formation damage, and so optimally a fracing program would be designed to create smaller fractures with deeper extension into the reservoir. In addition, restricting the conductivity will actually decrease the damage to the formation.

Dr. Brant Bennion
(Photo courtesy of Jeff Dickson)

In formations with higher permeabilities, actually performing the frac can lead to phase trapping problems, where a desiccated and hydrophilic formation will be exposed to a large influx of the fracing fluid (especially if this is water-based). There are currently developments in utilizing non-trapping fluids however.

Given the number of unconventional gas reservoirs currently in production in Canada and the USA, this talk certainly highlighted some of the key considerations that need to be made in characterizing these reservoirs, and developing completion strategies that can be used to best exploit them.

Jeff Dickson

Potash Redux

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Introduction

Potash was a hot topic in the early 1960's when I was a young logging engineer assigned at Lanigan, SK with one operator and a breadwagon (equivalent to today's "cube-van"). We dripped oil-base mud into the motel and all along the Yellowhead from Saskatoon to Yorkton. Recent potash price peaks have encouraged a renewed interest in potash, and numerous email inquiries based on my 1964 work to calibrate gamma ray log response to potash ore grade, co-written with Bill Anderson. For those who are unfamiliar with potash, and those who are tired of the ordinary grind, looking for romantic adventure, this story may be a useful escape from the four walls of today's more mundane petrophysical models.

Potash Basics

Potash refers to potassium compounds and potassium-bearing minerals, the most common being potassium chloride. The term "potash" comes from the old method of making potassium carbonate by leaching wood ashes and evaporating the solution in large iron pots, leaving a white residue called "pot ash".

Figure 1: Potash salt core, slabbed and ready for inspection

Later, "potash" became the term widely applied to naturally occurring potassium salts and the commercial product derived from them. The main potash salts are sylvite, carnalite, langbeinite, and polyhalite, mixed in varying concentrations with halite (rock salt). The main use of potash is as fertilizer.

Sylvinite is the most important ore for the production of potash in North America. It is a mechanical mixture of sylvite (KCl, or potassium chloride) and halite (NaCl, or sodium chloride). Most Canadian operations mine sylvinite with proportions of about 31% KCl and 66% NaCl with the balance being insoluble clays, anhydrite, and in some locations carnallite. Sylvinite ores are beneficiated by flotation, dissolution-recrystallization, "heavies" separations, or combinations of these processes.

The major source of potash in the world is from the Devonian Prairie Evaporite Formation in Saskatchewan, which provides 11 million tons per year. Russia is second at 6.9 million and the USA (mostly from New Mexico) at 1.2 million tons per year. A dozen other countries in Europe, Middle East, and South America produce potash from evaporite deposits.

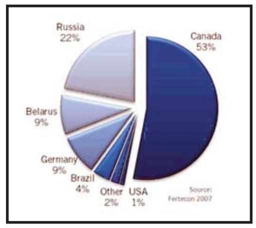

Figure 2: Potash production statistics 2010

Potash can be mined mechanically by underground machinery or by solution mining using ambient or warmed water. Halite (salt) for human use or road de-icing can be mined the same ways. Potash ores contain halite as well, so the by-product of potash extraction is road salt. In earlier times, salt was more valuable per ounce than gold, as it was essential to human life. A person "worth his salt" was one who contributed his fair share to the community.

The word potash is used in several different contexts in the literature. Here are some variations:

Table 1 Common Name	Chemical Name	Formula
Potash fertilizer	potassium oxide	K_2O
Caustic potash or potash lye	potassium hydroxide	KOH
Carbonate of potash, salts of tartar, or pearlash	potassium carbonate	K_2CO_3
Chlorate of potash	potassium chlorate	$KClO_3$
Muriate of potash (MOP)	potassium chloride	KCl
Nitrate of potash or saltpeter	potassium nitrate	KNO_3
Permanganate of potash	potassium permanganate	$KMnO_4$

Petrophysical Properties of Potash

Potassium is radioactive so the gamma ray log is used to identify potash bearing zones. Potash minerals have distinctive physical properties on other logs, so conventional multi-mineral models can be used to determine the mineral mixture, just as we do in carbonates in the oil and gas environment.

For consistency, potash ore and fertilizer concentrations are rated by their equivalent K2O content. Some literature can be

Continued on next page…

Potash Redux *continued…*

Table 2 POTASH MINERAL PROPERTIES

Mineral	Halite	Sylvite	Carnallite	Insolubles	Langbeinite	Polyhalite	Units
Formula	NaCl	KCl	$KMgCl_3 \bullet 6H_2O$	Clay	$K_2SO_4Mg_2(SO_4)_2$	$K_2SO_4Mg(SO_4)(Ca(SO_4))_2 \bullet 2H_2O$	
Potassium (K) Content	0.00	0.524	0.141	0.08 - 0.10	0.188	0.130	weight fraction
Gamma Ray	0	747	200	120 - 150	268	185	API Units (linear tool)
Apparent K2O Content	0.00	0.63	0.17	0.10 - 0.15	0.225	0.156	weight fraction
Hydrogen Index	0.00	- 0.02	0.60	0.30 - 0.40	- 0.01	0.25	fractional
Sonic Travel Time	67.0	74.0	78.0	90.0 - 120.0	52.0	57.0	microseconds per foot
Density (log)	2.03	1.86	1.57	2.35 - 2.65	2.82	2.78	gram/cc
Density (true)	2.16	1.98	1.61	2.35 - 2.65	2.83	2.79	gram/cc
Photoelectric	4.72	8.76	4.29	1.45 - 3.50	3.56	4.32	capture units

confusing because they rate the ore by its potassium content (K) or potassium chloride content (KCl), The table above lists the physical properties of potash minerals, including K and K2O values. The GR (API units) entry in the table do not seem to match any known correlation, so some caution is urged.

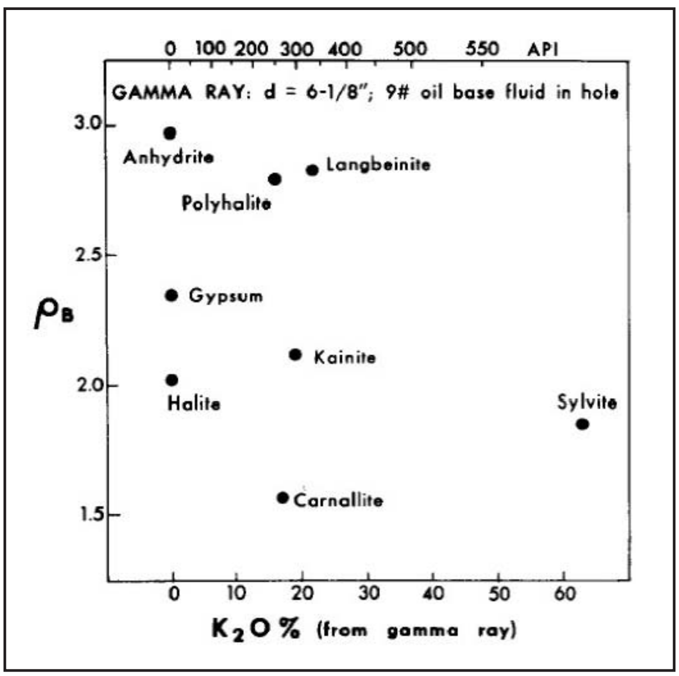

Figure 3: Gamma ray versus density crossplot of evaporite minerals used for mineral identification.

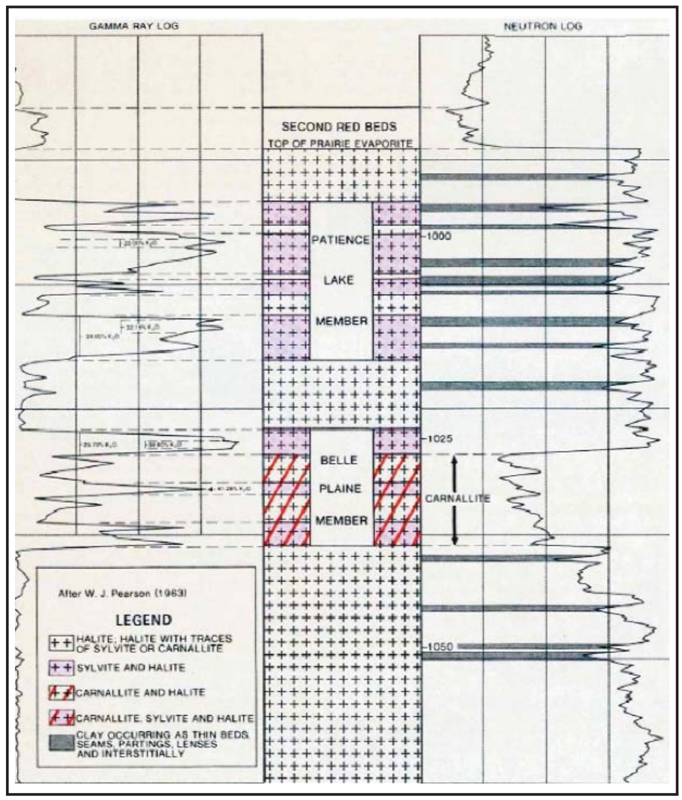

Figure 4: Example gamma ray and neutron log from Saskatchewan showing halite, sylvite, carnallite, and clay responses. In the exploration heyday in Saskatchewan in the 1960's, we presented the gamma ray across 3 tracks of the log, giving a scale of 0 to 450 API units (or 0 to 600) across 7.5 inches of paper. This was sufficient resolution for accurate evaluation and eliminated the need for GR backup curves cramped into Track 1.

Potash Analysis Concepts – Older Logs

Since potassium is radioactive, the K2O content can be derived from gamma ray logs, and this technique has been used since the 1960's. In 1964, I was stationed in Lanigan, Saskatchewan to run logs in potash exploration wells. While there, I scrounged a personal tour of the Esterhazy potash mine, then only two years old. This was the first and only time I have seen geological structure and stratigraphy from the "inside" of the rock. Truly amazing!

No direct calibration between GR and K2O had been developed up to that time, so I convinced a client to let me see his core assay data. After adjusting for hole size, mud weight, and bed thickness, a reasonable relationship was found, and was published as "Quantitative Log Evaluation of the Prairie Evaporite Formation of Saskatchewan" by E. R. Crain and W. B. Anderson, Journal of Canadian Petroleum Technology, Quebec City and Edmonton, July—September, 1966.

The work was subsequently reprinted in five other papers by various authors, some included updates as tool technology evolved. The original GR correlation was unchanged, widely distributed, and was the standard for potash analysis from oil-field style logs run prior to the era of digital logs in the 1980's. Most analog oil field GR logs were non-linear above about 300 API units due to dead time in the counting circuit. These older logs are still available in the well files and were recently used by Saskatchewan Industry and Resources to update their potash isopach and ore grade maps.

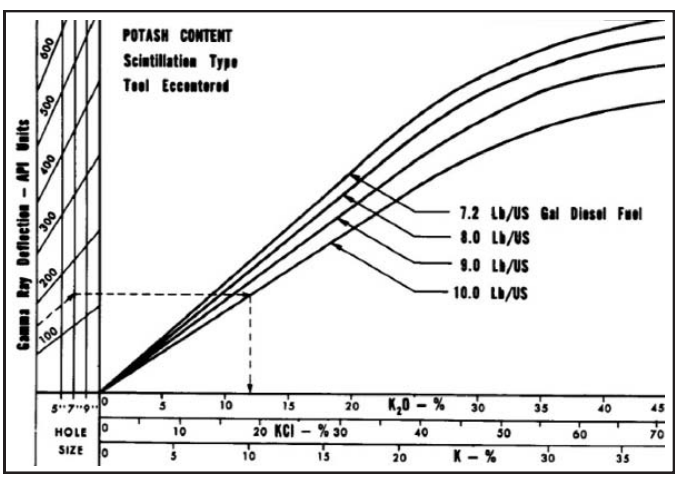

Figure 5: K2O versus Gamma Ray relationship for analog Sclumberger tools circa 1960 - 1980, run in open hole with oil based mud. Tools from other service companies may differ. Correlation between log and core assay data for specific cases is strongly recommended.

Gamma Ray Borehole Corrections

The hole size and mud weight corrections derived from the data, and embedded in the above chart, were:

1. GRh = GR * (1.0 +.0.05 * (HS - 6.0)) + (320 * (HS - 6.0)) / (GR + 100.0)

2. GRc = GRh * (1.0 + 0.10 * (WM - 7.2))

Where:
GR = gamma ray log reading (API)
GRc = GR corrected for hole size and mud weight (API)
GRh = GR corrected for hole size (API)
HS = hole size (inches)
WM = mud weight (lb/gal)

Potash Ore Grade From Gamma Ray

K2O content was derived from GRc using the lookup table shown at the right. It is linear up to 400 API units and exponential thereafter. Values in the table represent a 6 inch borehole filled with diesel at 7.2 lb/gal. The linear portion of the lookup table is represented by:

3: IF GRc <= 400

4: THEN K2O = 0.05625 * GRc

5: OTHERWISE
Use Lookup Table

K2O from GRc

GR API	K20
0	0.0
45	2.5
90	5.0
135	7.5
175	10.0
220	12.5
265	15.0
310	17.5
355	20.0
400	22.5
435	25.0
470	27.5
505	30.0
530	32.5
550	35.0
565	37.5
580	40.0
590	42.5
600	45.0
605	47.5

The slope in the above equation can be determined by correlation to core assay data for other hole sizes or other tool types.

The non-linear relationship must be honoured while analyzing these older logs for potash. The effect is negligible for conventional oil field applications. Modern digital tools are linear up to about 1000 API units so the discussion in this Section does not apply.

Continued on next page…

Potash Redux *continued…*

A 1967 paper showed a linear GR relationship up to 650 API units for the McCullough tool, but its use was not widespread in Canada. That graph showed 600 API units was equivalent to 45% K2O, identical to my original data, but the slope of the line at lower GR readings was different. No mud weight correction was implied but a bed thickness correction similar to mine was presented.

In the analog era, GR logs were calibrated to a secondary standard based on the API GR test pit in Houston which contained an artificial radioactive formation defined as 200 API units in an 8 inch borehole filled with 10 lb/gal mud.

However, there were no published borehole size or mud weight correction charts for the GR log. These effects are large enough to seriously compromise the correlation.

Bed Thickness Issues

Bed thickness corrections are also needed for beds less than 3 feet thick (1 meter). This is true even for modern logs. The chart shown at the right illustrates the importance of normalizing the GR log for these factors. Unfortunately, my original data plots for this work were lost in the bowels of a Schlumberger shredder many years ago - it would have been nice to recalibrate the work with the power of non-linear regression in a good statistics package.

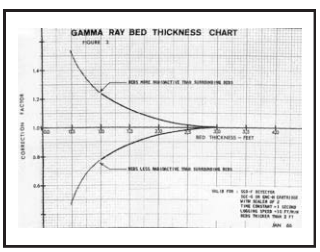

Figure 6: Empirical bed thickness correction chart for older GR logs

Non-Oilfield Gamma Ray Tools

Many potash exploration wells in the USA and elsewhere were logged with slim hole GR tools intended for uranium work. While they may have been more linear, they were not usually calibrated to any standard, suffered from larger borehole effects, and were recorded in counts per second (cps). Specific correlations to core assay data on a well by well basis are required for these wells. More on this later.

Using Ancient Neutron Logs

Due to the water of hydration associated with carnallite, the neutron log is very useful for distinguishing between carnallite and sylvite. High neutron count rates mean low hydrogen index, thus sylvite and not carnallite.

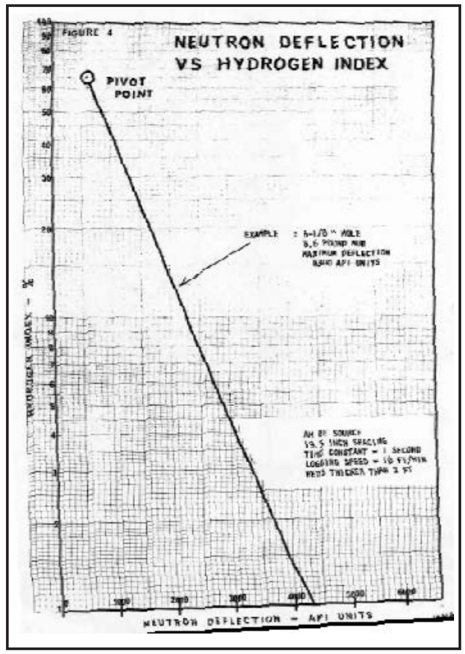

Figure 6: Empirical bed thickness correction chart for older GR logs

To quantify the relative amounts of carnallite and sylvite, the neutron response must be converted to porosity from count rates using the standard semi-logarithmic relationship. A typical transform for a 1960's era Schlumberger tool is shown at the right. Charts for other tools can be found in ancient service company chart books. With the advent of the sidewall neutron log in 1969 and later the compensated neutron log, this transform was no longer required.

Using Sonic And Density Logs

Some wells were logged with sonic and/or density logs which also could be used quantitatively with the GR and neutron to provide a potash assay. This was important where core was lost or for regional exploration when core data, but not the logs, were proprietary. The logic behind these models is shown below. A later Section of this article deals with the use of more modern logs.

Potash Analysis Models – Older Logs

My original computer program for potash analysis was written for the IBM 1620 in Regina in 1964. The model was based on four simultaneous equations that define the response of the available logs. Although this seems like a long time ago, nothing has changed except the improved tool accuracy. If you want to analyze the older log suites, here's how to do it.

The minerals sought are halite (rock salt), sylvite, carnallite, and insolubles or clay. The only logs available on old wells are resistivity, sonic, neutron, and total gamma ray. The resistivity is not a helpful discriminator, except as a shale bed indicator, so it is not used in the simultaneous solution. These evaporite beds contain potassium and ore grade is measured in units of potassium oxide (K2O). K20 is obtained from a gamma ray log, corrected for borehole size and mud weight, using a non-linear transform derived from core assay data. In middle aged wells, the density log is also helpful, and in modern wells the PE curve can be added. Further, the gamma ray response is linear on modern wells so the transform to K2O is not as difficult to obtain.

The equations are:

$$1.00 = Vsalt + Vsylv + Vcarn + Vclay$$

$$K20 = 0.00 * Vsalt + 0.63 * Vsylv + 0.17 * Vcarn + 0.05 * Vclay$$

$$PHIN = 0.00 * Vsalt + 0.00 * Vsylv + 0.65 * Vcarn + 0.30 * Vclay$$

$$DELT = 67 * Vsalt + 74 * Vsylv + 78 * Vcarn + 120 * Vclay$$

K2O is obtained, after borehole correcting the GR, from the equations and lookup table shown earlier, or from a fresh correlation based on specific data from the wells under study. Note that the chart and table given earlier are in percent K2O and this set of equations expects fractional units for K2O, neutron porosity, and all output volumes. Parameters in the sonic equation are in usec/ft.

When solved by algebraic means, these equations become:

1: $Vclay = 0.0207 * DELT - 0.23 * K20 - 0.29 * PHIN - 1.3891$

2: $Vcarn = 1.54 * PHIN - 0.46 * Z$

3: $Vsylv = 1.59 * K20 - 0.41 * PHIN + 0.04 * Z$

4: $Vsalt = 1.00 - Vclay - Vsylv - Vcarn$

These equations were derived with DELT in usec/ft. All constants will be different if DELT is in us/m.

To convert from mineral fraction to K2O equivalent (K2O equivalent is the way potash ores are rated), the final analysis follows:

5: $K2Osylv = 0.63 * Vsylv$

6: $K2Ocarn = 0.17 * Vcarn$

7: $K2Ototal = K2Osylv + K2Ocarn$

Effect Of Occluded Water

If occluded water (V) is added to the desired results, the equations become:

$$1.00 = Vwtr + Vsalt + Vsylv + Vcarn + Vclay$$

$$K20 = 0.00 * Vsalt + 0.63 * Vsylv + 0.17 * Vcarn + 0.05 * Vclay$$

$$PHIN = 1.00 * Vwtr + 0.00 * Vsalt + 0.00 * Vsylv + 0.65 * Vcarn + 0.30 * Vclay$$

$$DELT = C + 67 * Vsalt + 74 * Vsylv + 78 * Vcarn + 120 * Vclay$$

Where:

Vwtr = PHIN value in pure salt above the zone of interest.

C = DELT in salt minus 67 usec/ft.

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Potash Redux *continued…*

Reduction of these equations results in:

8: $Vclay = 0.0207 * (DELT - C) - 2.23 * K20 - 0.29 * (PHIN - V) - 1.3891$

9: $Vcarn = 1.54 * (PHIN - V) - 0.64 * Z$

10: $Vsylv = 1.59 * K20 - 0.41 * (PHIN - V) - 0.04 * Z$

11: $Vsalt = 1.00 - Vsylv - Vcarn - Vclay - Vwtr$

These equations show the use of constraints (Vwtr and C) on the otherwise underdetermined linear simultaneous equations. The first set of equations is exactly determined, and the second set are underdetermined until Vwtr and C are defined. If the density or PE equation were added, then the set would be exactly determined and the strategy of finding Vwtr and C in the pure salt bed would not be needed. This work was done in Saskatchewan before density logs were common, so the density equation was not used at that time.

Potash Mass (Weight) Fraction

Conversion to K20 equivalent remains the same as before. Note that mineral fractions are in volume fractions. To convert to weight fraction, one more step is needed. By using the density of each mineral times the volume fraction, summing these to get the total rock weight, then dividing each individual weight by the rock weight, we get weight fraction of each. This allows comparison to core assay data which are reported in weight fraction or percent. The same math is used in tar sands and coal analysis to allow comparison to lab data:

12: $WTclay = Vclay * 2.35$

13: $WTcarn = Vcarn * 1.61$

14: $WTsylv = Vsylv * 1.98$

15: $WTsalt = Vsalt * 2.16$

16: $WTwtr = Vwtr * 1.10$

17: $WTrock = WTclay + WTcarn + WTsylv + WTsalt + WTwtr$

Mass fraction or weight percent values are obtained by dividing individual weights by WTrock. for example:

18: $Wsylv = WTsylv / WTrock$

19: $Wcarn = WTcarn / WTrock$

20: $WT\%sylv = 100 * Wsylv$

21: $WT\%carn = 100 * Wcarn$

Where:

Vxxx = volume fraction of a component

WTxxx = weight of a component (grams)

Wxxx = mass fraction of a component

WT%xxx = weight percent of a component

Potash Analysis Models – Modern Logs

With a modern suite of calibrated logs, we can use conventional multi-mineral models to calculate a potash assay. With GR, neutron, sonic, density, and PE, we can solve for halite, sylvite, carnallite, clay (insolubles or shale stringers), and water (occluded in many salts as isolated pores). The potassium curve from a spectra gamma ray log might also prove useful, if the detector system is linear and does not saturate.

The mathematical methods are similar to those shown above, except that more log curves can be added to the simultaneous equation set, and constraints for occluded water can be replaced by specific numerical solutions.

If other potash minerals are present, such as polyhalite, these can be added to the equation set if enough log curves are available to maintain an exactly- or over-determined solution. Matrix rock properties for the minerals were shown earlier in this article. Water is treated as a "mineral" so that it can be segregated from the water of hydration in carnallite.

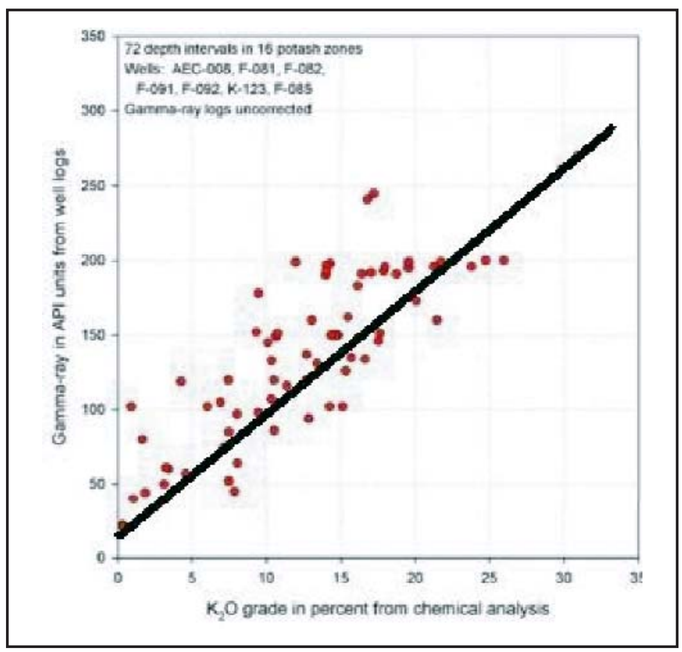


Figure 8: K2O vs GR correlation for a modern GR log

The first step is to correct the gamma ray for borehole and mud weight effects, using the appropriate service company correction charts. The other logs seldom need much correction as the potash is not especially deep or hot. However, if a water based mud was used, it will have a high salinity, so a salinity correction for the neutron log may be required.

The second step is to confirm the GR to K2O correlation using any available potash core assay data. Since modern GR logs are more linear than older tools, the relationship should be a relatively straight line and can be extended beyond the available core data, as shown in Figure 8.

Special Cases

There are numerous situations which require special treatment and some imaginative work-arounds by the petrophysicist.

Incomplete Logging Suite

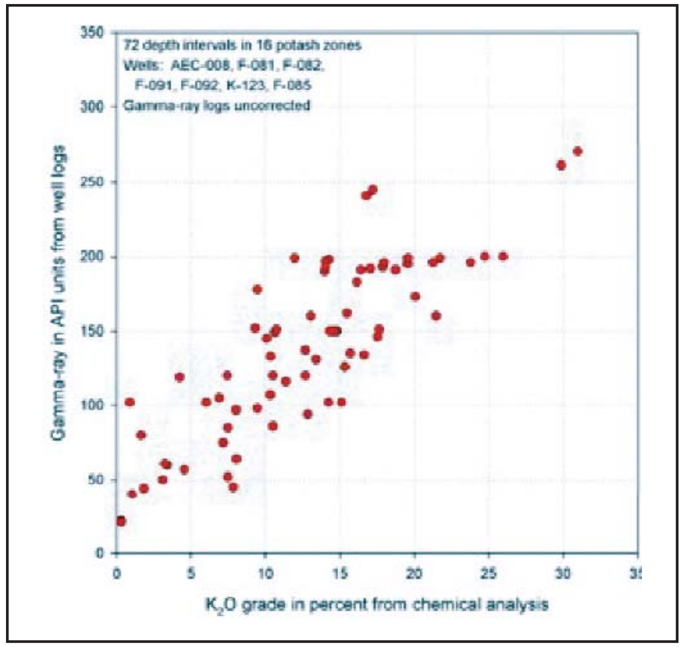
Here we must include fewer minerals in the model. Isolated water is easy to ignore, and insoluble clay comes next, although it is an important economic factor in the extraction process. In the worst case, we might need to settle for K2O from the gamma ray and a sylvite / carnalite discriminator based on the neutron log. This situation occurs most often when potash geologists are using logs in wells drilled originally for oil or gas, in which potash evaluation was not considered as a priority.

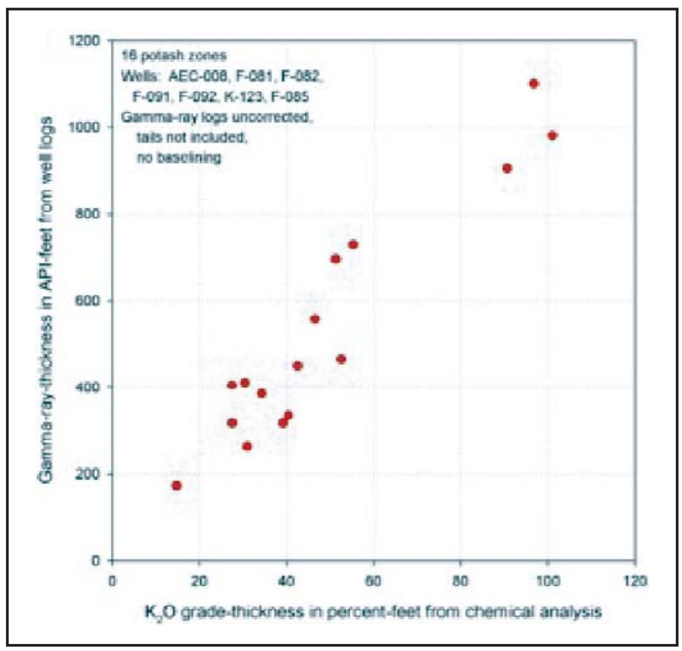
Through Casing Logs

The most obvious problem will be to correct the gamma ray log for casing size and weight, cement sheath thickness, and borehole fluid weight using service company correction charts. Where core assay data is available from the well or from reasonably close offsets, the GR to K2O relationship can be confirmed. The second problem is usually an incomplete logging suite, as described above. If a through casing neutron log is available, scaled or not, a carnallite flag can be created.

Thin Bed Problems

This issue affects all logs used for all purposes, but can seriously affect potash evaluation in areas where thin beds predominate. An approach was shown earlier using a bed thickness correction chart. Another approach is to correlate K2O times thickness to GR times thickness instead of a direct GR to K2O transform. This is best suited to hand picked data, as thickness is not so easily determined automatically in most log analysis software. The US Geological Survey published an example, originally developed by Jim Lewis of Intrepid Mining for a New Mexico case study. The pertinent crossplots from his work are shown below. The regression has much less scatter on the GR times thickness plots. This method was originally suggested in a 1967 paper describing the use of McCullough GR logs for potash evaluation.





Figures 9A and 9B: GR in API units vs K20 (left) shows poor correlation due to thin bed effects. GR-thickness vs K2O-thickness products (right) correlate much better (regression lines not shown).

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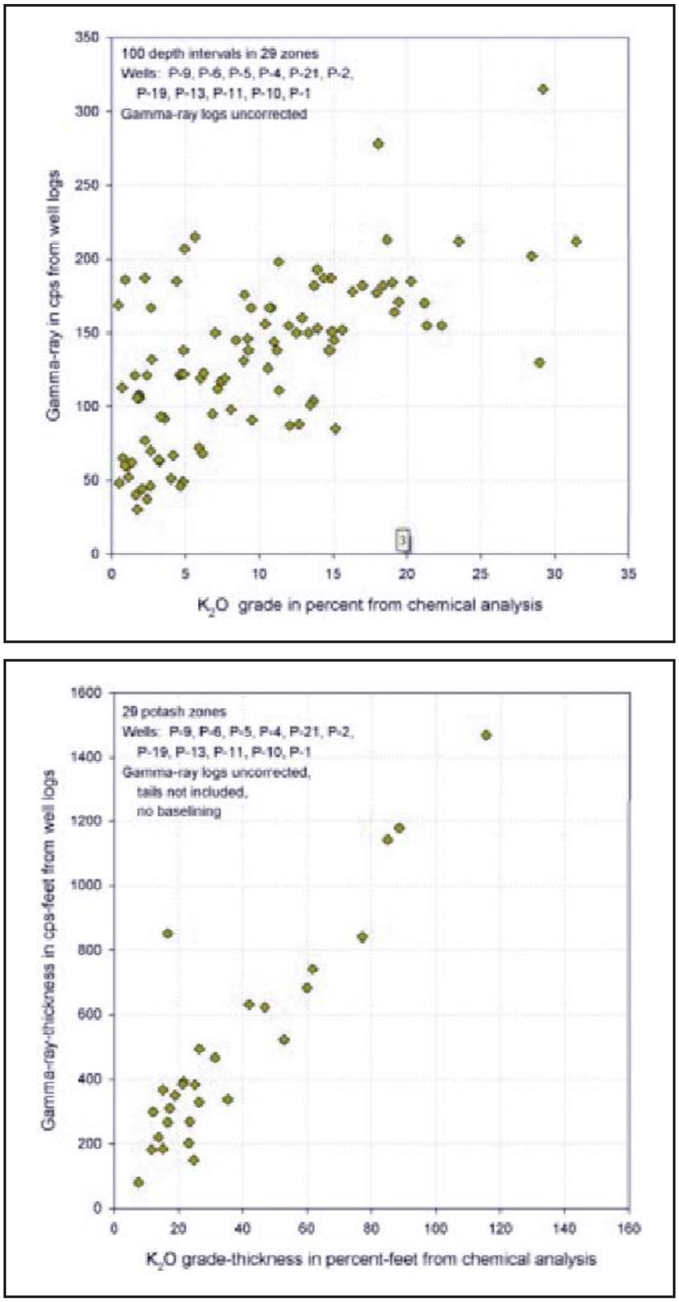
Potash Redux *continued…*



Figures 10A and 10B: /Similar graphs for some USGS GR data in cps show that the GR-thickness product is a better predictor of potash content than GR by itself in thinly bedded potash zones.

GR in Counts per Second

Many potash wells are drilled as stratigraphic test wells and are not intended to be completed. They are often drilled as slim holes and slim hole GR logs must be run. Some of these logs may be calibrated to the API GR standard; many are not. In any case the GR to K2O correlation must be established for each tool type and adjusted if mud weight or borehole size varies between wells. Bear in mind that the core retrieved from a slim hole is volumetrically much smaller than full size cores. Variations between log and core data is expected to be somewhat larger in slim holes.

Combinations of the Above

It would be unusual if there were no problems to solve. Logs run in different areas by a variety of service companies need to be normalized to some single standard. Borehole and casing effects need to be handled first. Then normalizing oilfield and strat hole gamma ray logs can be done by correlating potash beds between near offset wells. It would be nice if both wells also had core assay data but this is seldom the case.

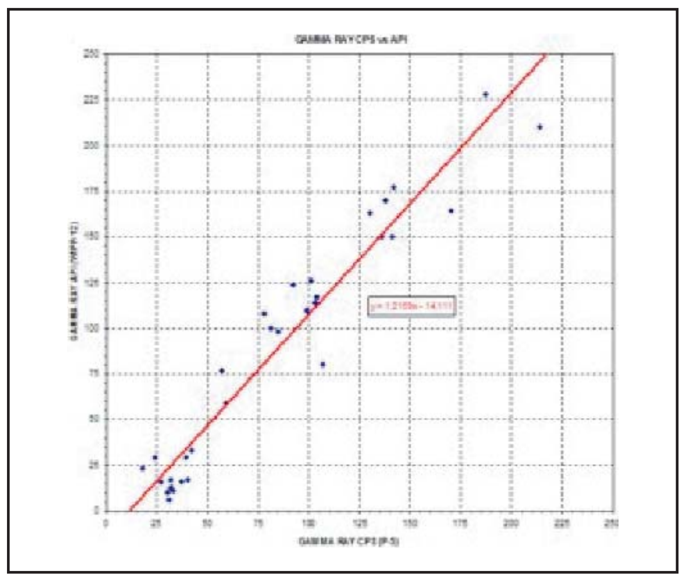


Figure 11: Comparison of USGS log picks over 29 potash intervals showing the regression against the API units for the same zones in the nearest oilfield well.

The equation of the line can be used to convert all USGS logs to API units in this particular project area.

Potash Analysis Examples – Older Logs

A sample of computed results from this log analysis model compared to core data is shown below. The GR was borehole corrected but no bed thickness corrections were applied.

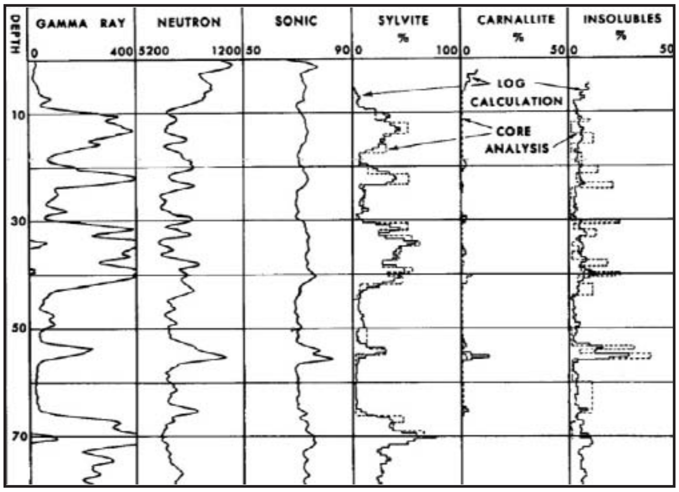


Figure 12: Example log analysis showing excellent match to core data (Crain and Anderson, 1964). Raw data is shown but note the scales are opposite polarity to normal oilfield presentations.

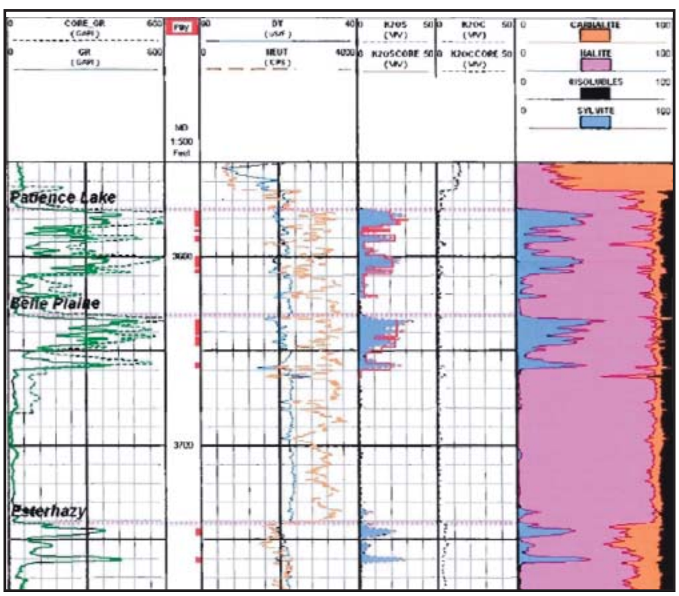


Figure 13: Potash evaluation of 1960's logs with a modern log analysis program using Crain and Anderson's original algorithms, calibrated to core data (see data in K2OS and K2OC tracks). Example log analysis courtesy Encanto Potash, analysis performed by Chapman Petroleum Consultant.

Continued on next page…

Potash Redux *continued…*

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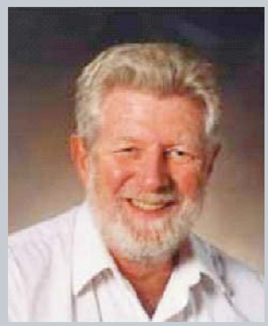
About the Author



E. R. (Ross) Crain, P.Eng. is a Consulting Petrophysicist and a Professional Engineer with over 45 years of experience in reservoir description, petrophysical analysis, and management. He has been a specialist in the integration of well log analysis and petrophysics with geophysical, geological, engineering, and simulation phases of oil and gas exploration and exploitation, with widespread Canadian and Overseas experience.

His textbook, "Crain's Petrophysical Handbook on CD-ROM" is widely used as a reference to practical log analysis. Mr. Crain is an Honourary Member and Past President of the Canadian Well Logging Society (CWLS), a Member of Society of Petrophysicists and Well Log Analysts (SPWLA), and a Registered Professional Engineer with Alberta Professional Engineers, Geologists and Geophysicists (APEGGA).

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Notes: Please forward this notice to any potentially interested co-workers. Thank you.

CANADIAN WELL LOGGING SOCIETY

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Wednesday, December 8th, 2010

CWLS TECHNICAL LUNCHEON PRESENTATION
FAIRMONT PALLISER HOTEL
133, 9TH AVE. S.W. CALGARY

TIME: 12:00 PM

RESERVATIONS BY: Friday, December 3rd, 2010 (NOON) - CALL 269-9366 TO CONFIRM A SEAT

COST: MEMBERS RESERVED MEAL: $40.00; NON-MEMBERS RESERVED MEAL: $45.00
(SPECIAL NEEDS MEALS AVAILABLE WITH ADVANCED BOOKING ONLY; PLEASE REQUEST WHEN ORDERING TICKET)

TOPIC: **Integrated Evaluation of Unconventional Shale Reservoirs**

SPEAKER: **Samuel D. Fluckiger, Senior Petrophysicist, TerraTek**

ABSTRACT:

The biggest challenge faced in unconventional shale gas reservoirs is the fact that they are both heterogeneous and anisotropic. This heterogeneity occurs at multiple scales (core, sample, log) and needs to be characterized effectively in order to build proper scaling relationships for propagating information in a meaningful manner. TerraTek has developed an integrated workflow which identifies log scale heterogeneity (Heterogeneous Rock Analysis) and uses this scale of heterogeneity as a template for reservoir characterization. This characterization is accomplished by also defining core scale heterogeneity and using the relationship between core and log scale to come up with a representative sampling strategy for core measurements (TRA, Rock Mechanics, Petrology). Once this detailed characterization is complete, nontraditional log analysis methods (HRA) are employed to develop log scale models which can effectively propagate measurement information beyond the cored interval to the field and basin scale.

SPEAKER BIOGRAPHY:

Sam Fluckiger started his career with ten years experience at Schlumberger as a wireline field engineer, transitioning into log analysis and petrophysics. His experience includes conventional clastics from the North Sea (Europe) and Conventional carbonates in the Middle East. For the last four years he has been with TerraTek as a Petrophysicist in the data integration group, focusing on unconventional reservoirs and the integration of core and log measurements for reservoir characterization.

UPCOMING EVENTS

December 1, 2010

CWLS Fall Social

4:00 – 8:00 p.m.

The Garage Sports & Billiards

Eau Claire Market

195 - 200 Barclay Parade S.W.

December 8, 2010

CWLS Technical Luncheon

Fairmont Palliser Hotel

Lunch at 12:00 noon

February 23, 2011

AGM

Palliser Crystal Ballroom

Details to follow.

For ticket information, please contact:

Ashley Pessell
Ph: (403) 262-7714   Fax: (403) 269-2787
Email: apessell@apegga.org

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This ad is the first in a series

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